

Session B2: V&V for M&S with Hardware or Systems in the Loop

Session B2 leaders:

Co-Chairs: **Dave Bort** (JHU/APL) & **Bill Ormsby** (Naval Surface Warfare Center)

B2 Materials in Foundations '02 proceedings:

Paper

Validation of Hardware in the Loop (HWIL) & Distributed Simulation Systems (83 pp)

Bill Waite (Aegis Technology Group)

Alexander Jolly (RDEC, Army Aviation and Missile Command)

Steven J. Swenson (Naval Undersea Warfare Center)

Lt Col Seth Shepherd (US Air Force Electronic Warfare Evaluation Simulator
Test Facility)

Robert Gravitz (Aegis Technology Group)

Slides (may contain back-up materials and notes)

V&V for M&S with hardware or systems in the loop(including all manifestations of distributed simulations) (133 slides) [B2B in both pdf and ppt formats]

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Participants in this session are listed at the end of the Discussion Synopsis.

Discussion Synopsis (to provide perspective on papers & briefings identified above).

Session B2, on “V&V for M&S with Hardware or Systems in the Loop (including all manifestations of distributed simulations)”, focused on the Invited Paper *Validation of Hardware-in-the-Loop (HWIL) and Distributed Simulation Systems*, by W. F. Waite, et al. Bill Waite, Lt. Col. Seth Shepherd, and David Curry (for author A. C. Jolly) were on hand to present the material and join in the ensuing discussion. The paper collected lessons learned from three military services, and used these to abstract the implications of various issues facing HWIL and distributed simulation systems, closing with some suggested directions for future research or standardization activities. While the focus of the paper, and of much of the discussion, was largely concerned with Department of Defense (DoD) simulation applications, the issues involved have broader applicability to other simulation areas. Significant points addressed during the discussion are captured below, organized into general subject areas, but not in order of priority. Where possible, issues with broader applicability than their original discussion areas are grouped accordingly. For instance, an issue originally discussed in the HWIL/distributed

simulation context, that is judged to have bearing in a broader verification and validation (V&V) context, may be listed in that group.

General Issues

The terminology used to describe V&V activities was described as somewhat confusing, rather than consistently illuminating. While there is no shortage of policies, procedures and guidance for verification, validation, and accreditation (VV&A) among the DoD services (all of which were referenced in the briefing), and while modeling and simulation (M&S) glossaries exist to assist in the necessary collaboration, the V&V practices that are aimed at improving the credibility of M&S are subject to the limitations of effective communication. Therefore, just as we expect our M&S developers to be precise in their model specifications, V&V practitioners are well advised to be precise, both in their use of the vernacular, and by thorough articulation of the implied context.

The nomenclature used for V&V is a recurring issue. Careful qualification of terms is necessary. For instance, the term HWIL may, in certain systems, include a software component that runs on a certain processor in the real system. This point is not readily apparent in the term HWIL alone. Further, certain terms are often “overloaded” in different situations, meaning the same term takes on different meanings in different contexts. For example, the term “validation” may mean different things to different simulation communities, and even a seemingly simple term like “graph” can have a wide range of meaning. Finally, different terms are sometimes used to mean the same thing, such as using either “HWIL” or “HILT” to mean hardware-in-the-loop. All these situations illustrate the need to pay particular and careful attention to the careful identification of terms, in order to avoid confusion.

HWIL and Distributed Simulation Issues

A tendency exists to think that the hardware used in HWIL systems “is what it is”. While it is true that an existing hardware’s components characteristics speak for themselves, the V&V practitioner must evaluate what specific behavior of the overall spectrum of allowable behavior for the hardware production run is actually represented. Further, the role of HWIL testing (and distributed simulation testing) must be clarified with respect to its place in the overall set of testing to be done. HWIL testing (and to an extent, distributed simulation testing, when using hardware components) is limited to representing a certain *instantiation* of behavior, out of the full set of possible behavior. It cannot effectively represent the entire system performance space or exhibit the entire range of possible behavior. It is extremely useful as a validation tool for other all-digital simulation tools, however. In fact, distributed simulation tools comprised of high-fidelity components may be able to provide better answers than any one component alone. But, effective V&V remains the enabling mechanism required to leverage such benefits.

Special treatment is required when an “HWIL” simulation system includes *software* components that normally run on other computing platforms and have aspects of their behavior that depend on their native platform environment, such as real-time characteristics, input/output transfer rates, and interrupt or flag interactions. Careful V&V is necessary to provide confidence that the

software components are providing adequate performance, within acceptable bounds, in the non-native environment.

Sensitivity analysis was identified as an effective means to mitigate risks associated with system information that may be unknowable, such as for threat systems. If changes to a given input parameter can be shown to have a small effect on system behavior, then the uncertainty associated with that particular becomes less of a critical issue. Parametric studies are another approach for dealing with this type of issue.

For HWIL and distributed simulation systems, it is important to document and verify not only the basic system components and architecture, but also the usage of the system. Typically, certain actions must be taken to put the system in a usable state that will generate correct results. For example, certain components may need to be initialized in a certain order, enabling applications may need to be configured properly, input data files must be properly selected, or output files may need to be appropriately named or located. Actions such as these, that are required to guarantee proper operation of the system, must be documented adequately to allow unambiguous identification of the proper procedures by any staff members that may operate the system. Further, benchmark check cases, comprised of a known set of results from a given set of input conditions, must be both documented and run before and after other simulation runs of interest. The preliminary benchmark run verifies that the system is operating as expected, then “runs for the record” are made, after which a concluding benchmark run verifies that the system is still able to run as expected after completing the runs for the record. Accordingly, documentation for the system must include such usage requirements as well as the typical description of system architectural details.

Data transfer rates used in HWIL and distributed simulation systems must be appropriate, not only for the literal interface specifications in question, but also for the intended use of the data. For example, an interface may support data rates between 0.1 and 100 Hz, but the data calculations to be performed on one side of the interface may yield misleading or erroneous results if the data rate falls below, say, 10 Hz. So, while a data rate of 1 Hz may be convenient for developers, it may not provide the intended results. Such derived requirements must be taken into account during the V&V of such systems.

Latency is an important consideration for HWIL and distributed simulation systems. It must be carefully characterized and managed to ensure it doesn’t negatively impact results.

Obtaining test data necessary to validate HWIL or distributed systems can be particularly difficult, especially if the V&V effort is not keeping pace with the associated development effort. Ideally, the V&V and development efforts will proceed simultaneously.

One point to remember is that production distributions associated with hardware used in HWIL simulations often represents a *truncated* Gaussian distribution, rather than a true Gaussian distribution, since “out-of-spec” components are discarded from the production lot. Accordingly, behavior at the extreme ends of the hardware component’s behavior may represent a larger percentage of the overall set of behavior than would otherwise be thought.

V&V Issues

It is important that V&V and development efforts occur simultaneously. For example, a stated Program Strategy must reflect this need early-on to maximize the likelihood of a V&V effort being effective. Also, simulation system developers and simulation testers should collaborate on the Test and Evaluation Master Plan. These types of actions will reflect, in the V&V program, the fact that the availability of a credible simulation is often an essential requirement for developing an effective system.

A team approach can be an effective mechanism for conducting V&V activities by helping to ensure that: (1) the maximum available information about actual system behavior and simulation system requirements is brought to light, and (2) all participants have a “stake” in the decision-making process. However, it is imperative that SMEs (Subject Matter Experts), simulation developers, V&V practitioners, test and evaluation personnel, and management staff all be represented. It is essential that effective system engineering practice and discipline be brought to bear, whether by SMEs or by designated system engineering staff.

Opening a V&V process widely to outside input can have the benefit of helping to clarify the scope of ongoing efforts. That it may also “inoculate” V&V practitioners against later criticism is only a secondary benefit, at best, since the entire community may suffer, in a sense, when efforts are sub-optimally performed. The primary point is that, in general, “Input is good.”

Although, in the general case, a given V&V program may be able to “do anything,” in practice, cost and schedule drivers often prevent a V&V program from “doing all things”. Therefore, careful prioritization of efforts is important to ensure that the risk mitigation available from the V&V effort is targeted to the most appropriate risk areas of the system under consideration. Risk determinations may be most effectively made by using a combination of factors, most prominently including the probability of occurrence, and consequences of occurrence.

One issue of significant interest was the availability of test data for validation of simulations, and the effective processes necessary for producing applicable validation data. In order for hardware tests to provide usable simulation validation data, and hence, greater return on investment, V&V planning must be integrated as early as possible into the development timeline. Early on, it may be appropriate to allocate as much as 100% of a test’s purpose to providing validation data. The use of test data for validation was recognized as being inextricably linked to a simulation’s intended use, while the collective process for linking data to an intended use – a key activity within effective V&V processes - was assessed as immature. Note that this maturity assessment was made for the average system development activity, that may not have a well-developed or early-integrated V&V component. Not surprisingly, interest in the details of process success stories was high, and the existence of isolated examples of more mature processes in this regard was noted, such as the STINGER and STANDARD Missile Programs. The use of metrics was recommended to associate intended uses for simulation validation data, defined early in the simulation development process, with test data collected throughout the development phases.

Several key process areas were recognized as essential in HWIL simulations to ensure data validity and applicability, including configuration management (CM), software quality assurance

(SQA), and operator training. The integration of all these disciplines is also recognized as important. For instance, V&V does not supplant the need for SQA or CM; rather, CM and SQA are seen as necessary and effective enabling processes for V&V.

One useful discussion concerned the practice of depicting worst case scenarios for blue forces (U.S. or Allied forces) in some HWIL simulations, and best case scenarios for red forces (threat representations) or environmental representations in other HWIL simulations. In the general case, for some HWIL or distributed systems, worst-case assumptions for the conditions associated with a given simulation component or set of input data may be appropriate to use, while for other systems, best-case assumptions may be more appropriate. For example, to operate a simulation system that robustly represents a missile intercepting an airborne threat (among other components), the missile may need to use worst-case assumptions, while the threat may use best-case assumptions. Appropriate justification for such decisions on assumptions used for the simulation system should be captured and identified in the V&V documentation set. Also, the aggregation of data in support of the information needs of a program must be performed with a solid knowledge of the conditions under which the data are collected.

An amusing but true statement can be made: “Force-on-force simulations rely on the kindness (or integrity) of strangers.” In this case, the strangers are the models or simulations that participate, or generate data for, the force-on-force simulation. It is important to note that the aggregate performance of such larger-scope tools is limited by the V&V-proven integrity of their constituent simulation components or data.

The potential for inconsistencies between assumptions used for HWIL simulations, which collect measures of performance of “as is” units under test (UUT), and those used for simulations employed for concept exploration, which characterize the expected performance of “paper” system designs, was raised as an issue that needs attention. Research investment in conceptual model documentation was recommended, in order to enhance the ability of V&V practitioners to more routinely clarify an effort’s distinct, if underlying, assumptions.

For HWIL and distributed simulation systems particularly, it’s said to be a “good day” when you understand your problems, a “bad day” when you don’t understand your problems, and a “nightmare” when you have no idea that you have problems. Effective V&V efforts are necessary not only to reduce occurrence of bad days, but also to try to eliminate nightmares.

Culture Issues

There is a need to go beyond simple identification of desired V&V approaches in documentation products; rather, the critical issue is seen to be *shepherding* the V&V process among system developers, simulation developers, and managers. For example, early in a development effort, clarifying to managers the expected benefits of effective early-on V&V efforts, as well as revealing the risks (both cost and schedule) of *not* mounting such efforts, can be expected to yield improved V&V planning decisions, compared to an approach that simply states that V&V should be used because it’s a “good thing.” During a development effort, partnering V&V staff with test and evaluation (T&E) staff can increase robustness of V&V planning. Further, working with simulation developers to illustrate how V&V processes can map to their existing techniques

and add value to ongoing efforts is considered much more effective than simply requiring V&V to “be done.” Finally, development investments in V&V must be followed by documented evidence of “return on investment” (ROI) to motivate continued commitment by management towards the pursuit of credible V&V-infused development practices.

One issue that appears to be a problem still to be worked in certain areas is the release of system description information that may be necessary to properly calibrate a given simulation system. Currently, some nations, and even some U.S. government agencies, have been reluctant to release information that may be important not only to V&V practitioners, but also to users of the eventual system to be built, which may suffer from the lack of requirements driven by non-released details of another system’s behavior. The “way forward” in this area is unclear, however, and may need to be worked on a case-by-case basis. Clear documentation of both the need and the consequences for failure to be forthcoming is certainly indicated.

The state of V&V approaches in use by different development communities is varied. In some areas, there exists a sort of “chicken-and-egg” problem, in that ROI may be more readily available only after the use of V&V has been institutionalized within a given organization. However, V&V use may not *be* institutionalized until after ROI is demonstrated, or at least predicted. Certainly, V&V approaches would likely be different for different organizations, but, just as certainly, V&V efforts need to be integrated with management, as well as developers and testers. Accordingly, there is an “educational” component of the overall V&V effort that must often be undertaken; this education outreach effort would serve to effectively communicate to managers the need for V&V early enough in the system development effort to allow it to be most effectively pursued. Failure to take up this educational burden may significantly curb the ability of a given V&V effort to effectively mitigate system risk.

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